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TITLE USE OF A GANTRY ROBOT IN THE ASSAY OF RADIOACTIVE MATERIALS

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USE OF A GANTRY ROBOT IN THE ASSAY OF RADIOACTIVE MATERIALS

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ABSTRACT

A large industrial robot has been installed in our plutonium processing facility to speed the assay of materials in process. The robot routinely transports radioactive items weighing 20 lbs or more between an automated inventory system and the analytical instruments.

Because the system operates unattended under computer control, assays are now performed around-the-clock instead of just 8 hrs per day, thereby greatly increasing the utilization of our instruments. (When the system becomes fully operational, we expect a four-fold increase in productivity.) In addition, recordkeeping has improved, the plutonium is better protected from theft, and our personnel are exposed to less radiation than before.

INTRODUCTION

In the Los Alamos National Laboratory plutonium facility, each batch of material that is being processed is frequently assayed for total plutonium content to detect theft. Because the matrix changes with each processing step, simply weighing the plutonium is insufficient; special radio-analytical instruments must be employed.

To remove a growing backlog of assays and to utilize our instruments better, we installed a robot that could serve the instruments around-the-clock. A typical laboratory robot could not be used, because the items we assay are too heavy. Accordingly, we chose an industrial, gantry robot.

Although the robot is much more expensive than typical laboratory robots, we determined that alternatives to the robotic system would not be as cost-effective. Simply buying more analytical instruments was not the answer, because a single instrument costs more than the robot! And hiring more personnel so we could work three shifts per day instead of just one was also judged to be prohibitively costly because of both labor costs and overhead.

EXPERIMENTAL

Operation of the System

The robotic system is shown in Figure 1. Its work begins when an operator packs radioactive material into a special cannister and puts the cannister into the industrial stacker-retriever (also

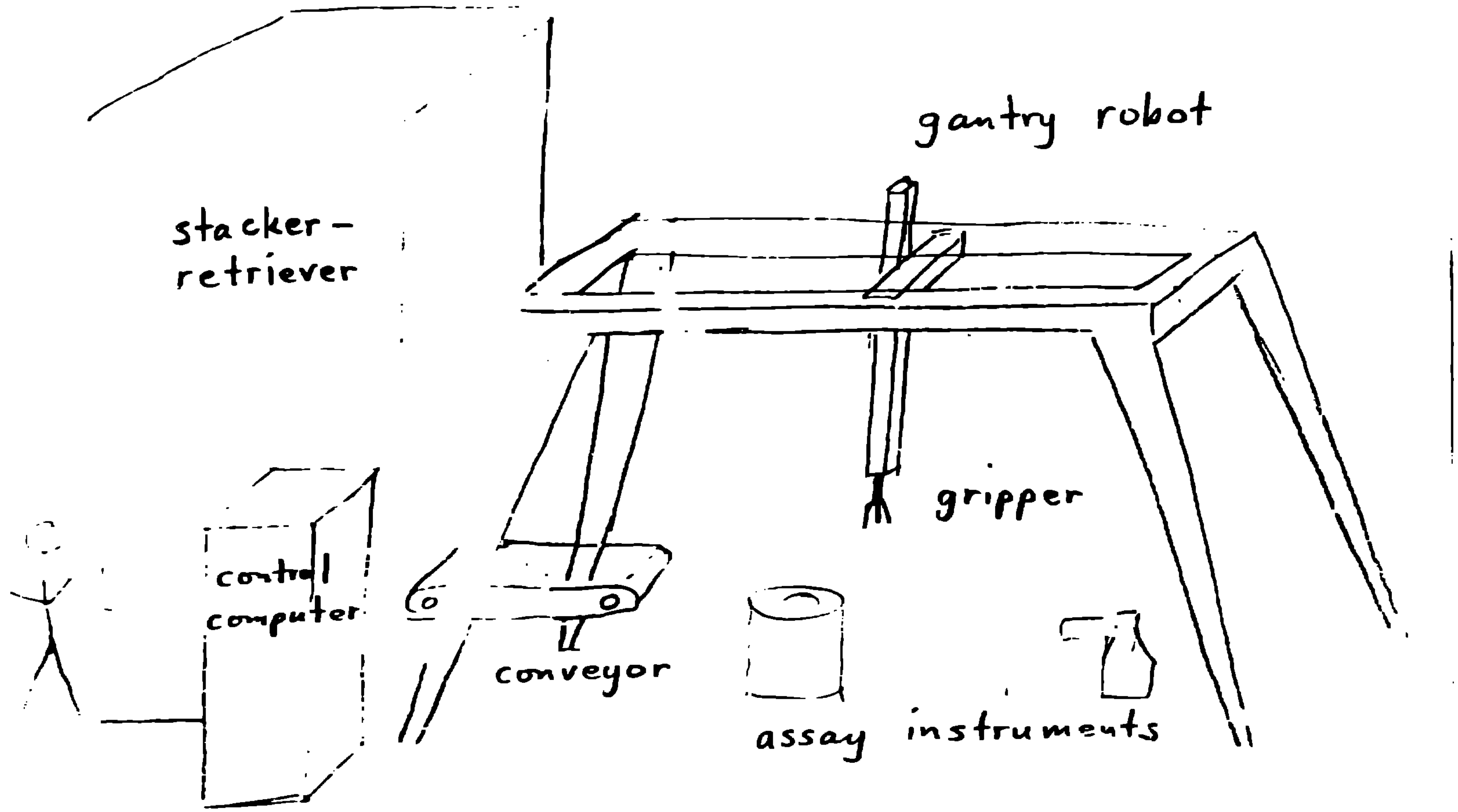

Fig 1. Components of Assay System

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called an "automated inventory system.") On command from the control computer, the stacker-retriever delivers the item to the robot's work envelope. The robot carries the item to a barcode reader (not shown) that confirms that the correct item has been delivered, then it puts the item into one of the assay instruments. When the assay is complete, the robot removes the item from the instrument and returns it to the stacker-retriever. Finally, the operator removes the item from the stacker-retriever.

Automated Inventory System

Details of the stacker-retriever (Industriever™ 8000, Kardex Systems Inc., Marietta, OH) are revealed in Figure 2. (That diagram depicts a unit with two modules, although our unit has three, but all the modules work the same way.) Outwardly, it is a large metal cabinet 12 ft wide, 10 ft deep and 16 ft tall. Internally, each module consists of two tiers of shelves which face each other and are separated by an elevator shaft. On each shelf is a metal tray that holds the items to be assayed. A dumbwaiter moves vertically through the shaft under computer control. When it reaches the desired shelf, a conveyor mechanism pulls the entire shelf onto the dumbwaiter. The dumbwaiter descends to the delivery level and pushes the tray out to the human attendant on one side of the unit or to the robot on the other side.

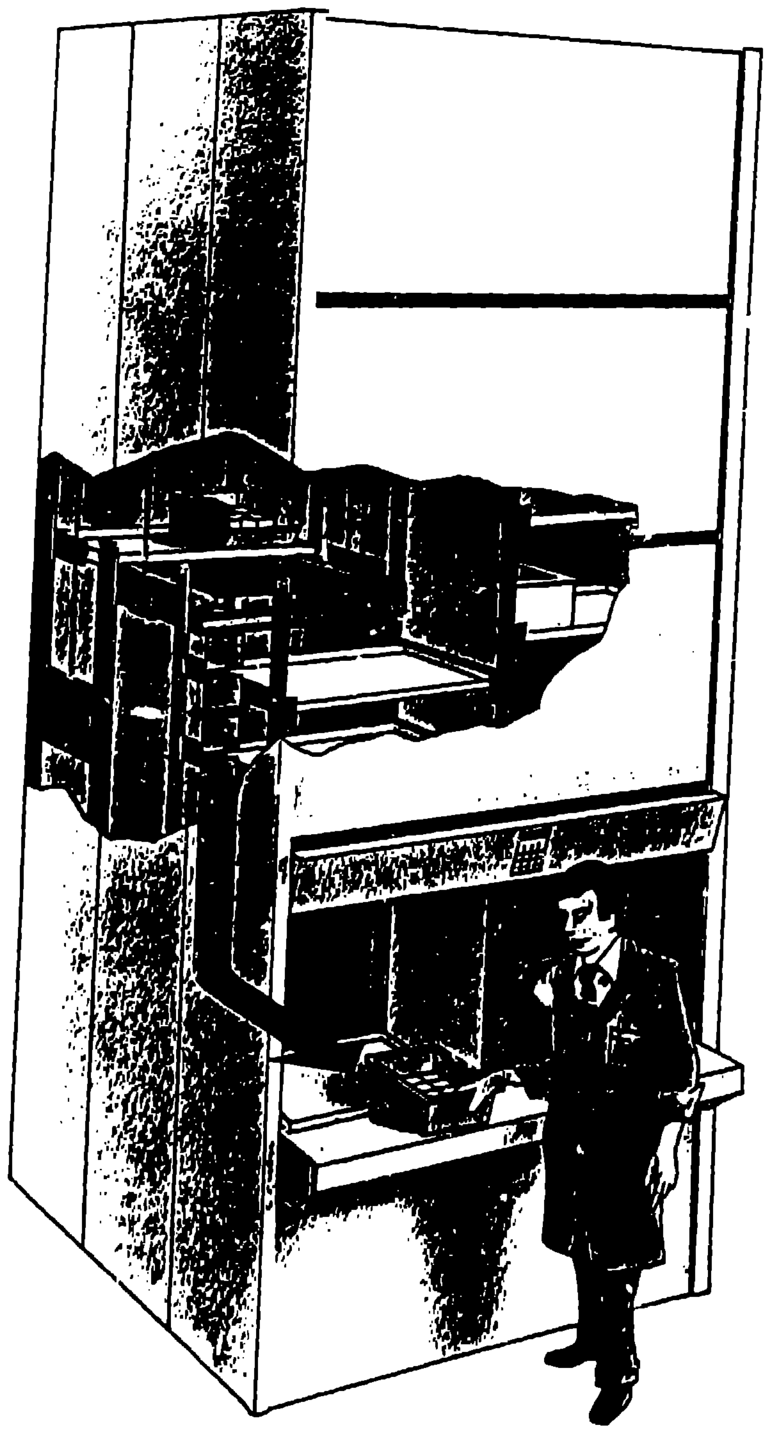

Fig. 2 Automated Inventory System
two-unit model

Gantry Robot

The robot (Model XR3050, Cimcorp Inc., Shoreview, MN) is depicted in more detail in Figure 3. The assembly consists of a rectangular runway structure about thirty feet long and 16 feet wide, which is supported at the corners by pedestals 11 ft tall. The runway structure guides and supports the bridge (X axis), which in turn guides and supports the carriage (Y axis). A vertical monomast assembly (Z axis) is mounted on the carriage. Rack-and-pinion drives provide precise linear axis movement in this rectangular coordinate system.

The dimensions of the work envelope are: 6 ft 8 in by 14 ft 4 in by 5 ft 9 in. The robot's maximum speeds are: 36 in/s (X and Y-directions), and 20 in/s (X-direction). It can carry as much as 200 lbs with a repeatability of +0.004 in.

The three-fingered gripper (Model GTP-45, Astek, Watertown, MA) is equipped with a six-axis force sensor (Model FS6-120A, Barry Wright Corp., Watertown, MA). The sensor employs strain-gage transducers to measure the linear forces or torques that may be applied to the gripper during operation.

Barcode System

Barcode labels are affixed to the lids of the cannisters that contain the material to be assayed. These labels provide positive identification for the cannisters. In the event the stacker-retriever or robot is inoperative, the analytical instruments can be serviced manually. The labels were specially

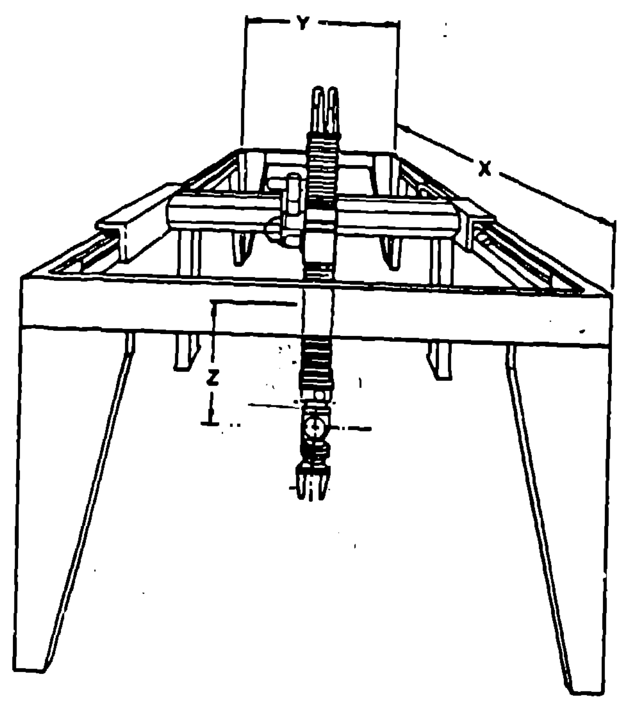

Fig. 3. End View of Gantry Robot
Showing Three Degrees of Freedom

designed by one of us (Staley) and custom-made (Innovative Products & Peripherals Corp., Englewood, CO), while the barcode readers (Model 6320, Symbol Technologies, Bohemia, NY) are standard items.

Analytical Instruments

The amount of fissionable material in each item is measured by first placing it in a calorimeter (custom-built by EG&G Mound Applied Technologies, Miamisburg, OH) and measuring the rate at which heat is produced by the radioactive decay of the material. The rate of heat generation also depends, however, upon the isotopic composition of the material.

Information about the isotopic composition is obtained from the gamma-ray spectrum of the material. The high-resolution spectrometers we employ for this were assembled from commercially-available components by John Fleishner (Rocky Flats Plant, Golden, CO) who also provided the associated electronic instrumentation and control computer.

Computer Control System

The control system is shown in Figure 4. The heart of this distributed system is the robot controller (Model Cimroc™ 4000, Cimcorp Inc., Shoreview, MN) that employs a personal computer (Model PC/AT™, International Business Machines Corp., Boca Raton, FL). However, the robot controller is itself under the control of another personal computer (Model Deskpro 386/20e™,

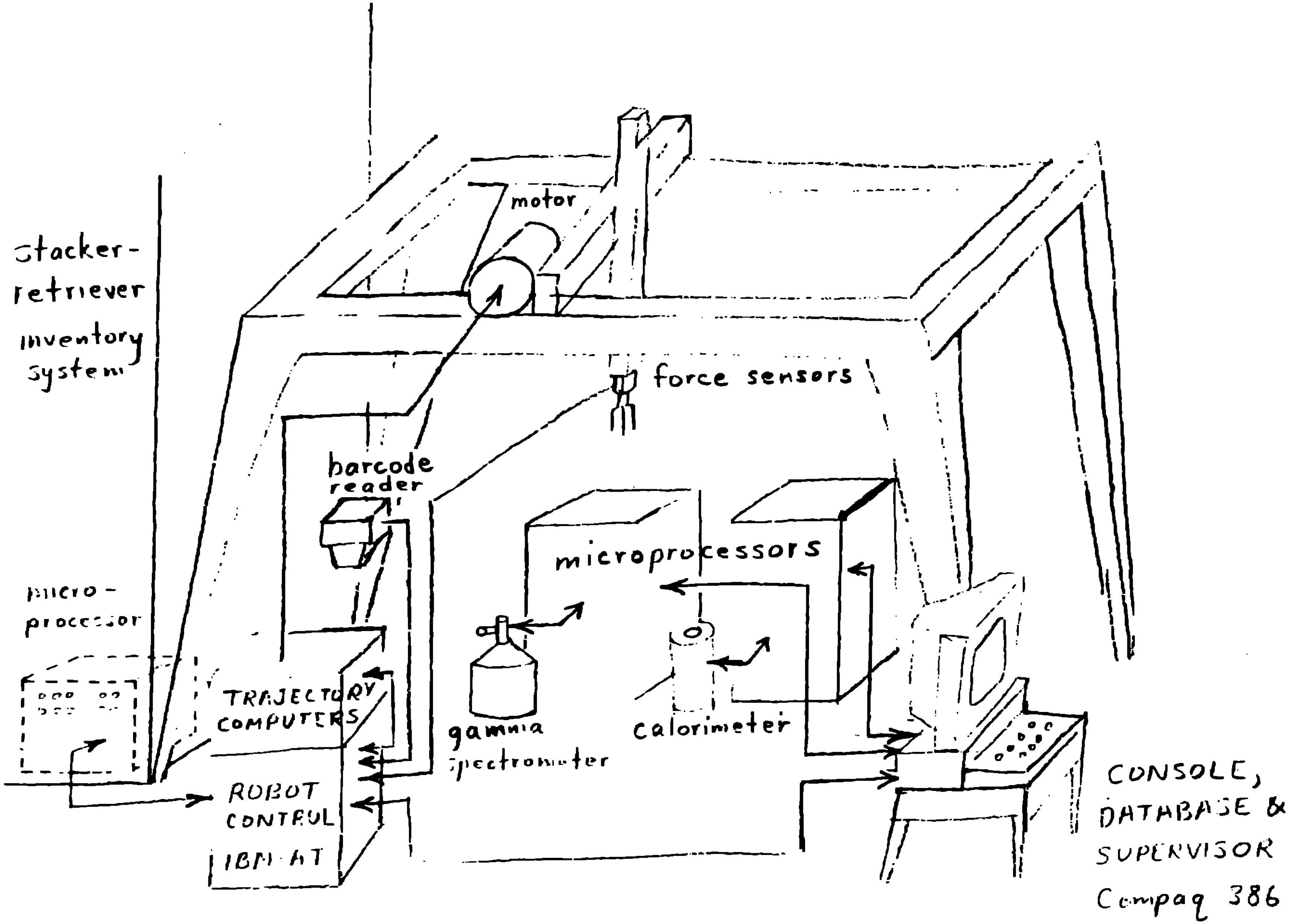

Fig. 4 Control System

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Compaq Computer Corp., Houston, TX) which serves as the operator's console.

The operator's console is used by our personnel when they put items into the stacker-retriever or remove them. The console also supervises the analytical instruments, communicating with their computers via serial interfaces. Furthermore, the console maintains the database of information relating to the items and their assay results.

The robot controller contains the robot's pre-programmed moves. These are executed upon command from the master program which is always running in the console. The commands are transmitted by the controller to three "trajectory computers," which in turn control the servo motors that drive the robot. As the robot is moving, the controller also monitors the force sensors in the fingers. Finally, the controller also communicates with the barcode reader and with the microprocessors that control the stacker-retriever.

RESULTS

Increased Productivity

The system is not yet fully operational, because not all of the analytical instruments have been transferred from the old laboratory. Nevertheless, the utilization of the instruments that have been installed has doubled. When the system is completed, we expect at least a four-fold increase in productivity, because the instruments will be used 160 hrs/wk instead of just 40.

Reduced Radiation Exposure to Personnel

The operating personnel now stay outside the room most of the time, and they handle the items only when they pack them into the special canisters that go into the instruments. Before, the operators also had to place the items into the instruments and remove them, and they had to watch the instruments to see when an assay was complete. Usually, they spent most of their working hours in the same room as the radioactive materials.

Improved Security for Materials

First, only authorized personnel who know the combination to the locked door of the room can get in, and we have been able to reduce the number of these personnel because our manpower requirements have been reduced.

Second, nowadays there is usually no one in the room unless they are putting material into the system or removing it. At those times, the personnel must work in pairs (a Department of Energy regulation) and sign-on to the computer with their passwords in order to make the stacker-retriever work.

Third, the operators have access to only one item at a time. All the other items remain in the locked stacker-retriever or in the robot's work envelope which is carpeted by pressure-sensing pads and surrounded by a "light curtain." If anyone enters the work envelope, an alarm sounds.

Finally, the chance for pilferage is reduced, because the robot weighs each item (using its force-sensing gripper) whenever the item is moved, and the weight is compared with that measured when the item was first put into the stacker-retriever.

DISCUSSION

Why an Industrial Robot

Two considerations forced us to use such a large robot. First, the items we handle often weigh 20 lbs or more. Second, the items must be moved about 10 ft between the stacker-retriever and the most distant instrument.

The items are so heavy because the batches of material themselves frequently weigh more than 5 lbs each, the stainless steel cannisters with their special lids weigh 8 lbs, and after the material is put into the cannisters, 10 lbs of metal shot is poured in to fill the void spaces. (The metal shot improves heat transfer to the cannister walls.)

Need for a Conveyor

Returning to Figure 1, you will note a short conveyor between the stacker-retriever and the robot. Because the stacker-retriever could not push items into the robot's work envelope and the robot, lacking a wrist, could not reach into the stacker-retriever for an item, we had to install something that could move items between those two units. In fact, conveyors were purchased (Kardex Systems Inc., Marietta, OH) for all three stacker-retriever modules, but we modified them extensively for our needs.

Special Holders for Canisters

To prevent the cannisters from falling over when they are being moved about inside the stacker-retriever, we designed special fixtures to hold them securely in their trays. Each tray carries a fixture and each fixture has four cylindrical holes 4 in deep into which the cannisters are placed. The fixtures were custom made of cast aluminum and, weighing 96 lbs each, they prevent the cannisters from tipping or sliding. The fixtures also help assure that the cannisters will be in well-defined locations when they are delivered into the robot's work envelope.

Need for Force-Sensing Fingers

Besides enabling the robot to weigh the items each time it lifts them, the sensors provide an important margin of safety when a cannister is being slipped into a calorimeter. The sensors can detect when a cannister is not going in properly, and the computer stops the robot from trying to force the cannister in farther. In addition, the sensors allow the robot to find a cannister even if it is farther from its expected location in the work envelope than normally allowed. This frequently occurs when a tray of cannisters is pushed into the work envelope by one of the short conveyors.

Safety Considerations

Several measures were taken to protect operating personnel from injury. It has already been noted that the robot's work envelope is surrounded by a "light curtain" and carpeted by pressure-sensing pads, so an alarm sounds if anyone enters the work envelope. In addition, whenever items are being put into or removed from the stacker-retriever, the operator must close the access door and press a key on the operators console before the stacker-retriever will operate.

Computer Control

For our situation, a distributed control system was the logical choice. For one thing, the analytical instruments were already being operating under the control of their own computers, and trying to integrate them into a central computer would have been prohibitively expensive. For another, there are times when the operation of robot is so computation-intensive that it requires a dedicated computer.

The software for the operator's console was written in Turbo PASCAL^{tm} (ver. 4.0) so it would be compatible with the code that controls the robot's moves. The code for the robot was provided by the manufacturer (Cimcorp Inc.) who had already written it in Turbo PASCAL^{tm}.

The user's interface was custom-made by one of the authors (Phelan) so it is especially easy for personnel to enter and remove items from the system. The software is menu-driven and provides for time-sharing, that is, between an operator's keystrokes, control is relinquished to the main program so that communication can be maintained with the instruments and other components of the system. As with the other software that resides in the operator's console, this was written in Turbo PASCAL[tm] so it would be compatible with that of the robot.

Detailed information about each item, including the results of the assays, is stored on-line in databases created with a commercial database manager (R:BASE for DOS[tm], Microrim Inc., Bellevue, WA). The Turbo PASCAL[tm] code communicates with the databases by means of a commercially-available utility (R:BRIDGE[tm], ver. 3.0, Synchronicity Research, Princeton, NJ).

SUMMARY

A industrial robotic system proved to be a cost-effective way of improving the throughput in an analytical laboratory. It also reduced the radiation exposure of operating personnel and improved the security for the material being assayed.

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